

On-farm farmers' participatory evaluation of intensification of rice (*Oryza sativa*)–rice–fallow system with vegetables in summer under humid tropical irrigated lowlands

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ABSTRACT

An on-farm field experiment was conducted in 24 farmers' fields in randomized block design with 5 treatments. Introduction of vegetables, viz. 'Vellayani Jyothika', yardlong bean (*Vigna unguiculata* L. ssp. *sesquipedalis*), 'Arka Anamika' okra (*Abelmoschus esculentus* L.), 'Saubhagya' oriental pickling melon (*Cucumis melo* L. var. *conomon*) and 'Arun' amaranth (*Amaranthus tricolor* L.) in summer fallow of traditional double crop 'Uma' rice (*Oryza sativa* L.) in a humid tropical irrigated lowland was attempted during 2009–13 at Pathanamthitta, Alapuzha and Kottayam districts of Kerala. System yield, soil-nutrient balance and economics of the systems were compared. Rice–rice–yardlong bean system could realize higher productivity and profitability. Recycling of yardlong bean residues back into system could add to actual N and K gain and overcome actual P loss observed in soil. Rice-grain-equivalent yield of rice–rice–yardlong bean was the highest (35.39 t/ha), followed by rice–rice–amaranth (28.65 t/ha). The lowest rice–grain-equivalent yield was recorded from rice–rice–fallow (10.63 t/ha). Rice–rice–yardlong bean had better sustainable-yield index (0.62), system productivity (96.96 kg/ha/day), land-use efficiency (91.79%), apparent nutrient-use productivity (118 kg/kg N, 221 kg/kg P₂O₅ and 177 kg/kg K₂O), net returns (₹ 252 × 10³/ha), sustainable-value index (0.40), system profitability (₹ 751/ha/day) and net returns per rupee invested (1.95) than the other systems. Soil-nutrient balance under rice–rice–yardlong bean showed gain of 39 and 47 kg/ha of N and K respectively.

Key words : Cropping systems, Diversification, Economics, On-farm evaluation, Rice-rice-fallow system

In Kerala, high population density of 859 persons/km² has given rise to a very small operational farm-holding size of 0.22 ha. Marginal and small farmers together constitute 99% of 68.31 lakh operational holdings. Rice is generally cultivated in Kerala during *kharif* (April–May to September–October), *rabi* (September–October to December–January) and summer (December–January to March–April) seasons. The state has a humid tropical climate, with high annual rainfall of 2,940 mm. Rice–rice–fallow cropping sequence is traditionally practiced in lowlands to take advantage of high monsoon rainfall. Rice–rice–fallow system occupies about 0.60 lakh ha in Kerala, with annual production of 2.72 lakh tonnes and productivity of 4.5

t/ha. Area of rice–rice–fallow system in Pathanamthitta; Alapuzha and Kottayam districts of Kerala, where the experiment was conducted, is estimated about 82; 6,653 and 2,229 ha, with annual production of 396; 36,609 and 12,043 tonnes and productivity of 4.9, 5.5 and 5.4 t/ha respectively. Annual income from rice–rice–fallow system is about ₹ 0.65 lakh/ha in Kerala and ₹ 0.71, 0.80 and 0.78 lakh/ha in Pathanamthitta, Alapuzha and Kottayam districts respectively. Income from double crop rice is hardly sufficient to sustain a farm family. Diversification of cropping system in lowland areas is difficult because of high clay content and longer duration lowland rice varieties (Rautaray *et al.*, 2015). Heavy clouding and monsoon rains in Kerala tend to slow down vegetative growth thereby increasing the normal *kharif* rice duration by 10 days, thus limiting the choice of crops and varieties for introduction into the system. Gangwar and Ram (2005) reported that intensification by inclusion of legumes in cropping system leads to significant improvement in pro-

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ductivity, profitability and soil fertility. Singh *et al.* (2012) observed that inclusion of vegetables in rice-based cropping system improved rice-equivalent yield, profitability and also provides regular returns to the farmer. Information pertaining to on-farm farmer participatory results on productivity and efficiency of traditional rice–rice–fallow system and its comparison with rice–rice–vegetables systems is meagre. Hence an on-farm field experiment was undertaken for comparing yield, soil-nutrient balance and economics under different rice-based intensifications in irrigated lowland field in Kerala.

MATERIALS AND METHODS

A fixed-site on-farm field experiment was conducted for 4 consecutive years from rainy (*kharif*) 2009 to summer 2013 in randomized block design and replicated in 24 farmers' fields. Farmers' fields located between 9°05' N and 10°21' N and 76°17' E and 77°25' E in Pathanamthitta, Alapuzha and Kottayam districts of Kerala in 6 blocks, viz. Parakode, Mavelikkara, Champakulam, Pallom, Ettumanoor and Kaduthuruthy were used for experimentation. Four villages were selected in each block. One farmer's field was identified in each village. Net plot size of 100 m² was allocated for each of the 5 cropping systems, viz. rice–rice–fallow, rice–rice–yardlong bean, rice–rice–okra, rice–rice–oriental pickling melon and rice–rice–amaranth. During *kharif*, rice variety 'Uma' with 115–120 days duration was direct seeded during the second fortnight of May and harvested in the second fortnight of September in all the years. In *rabi*, rice variety 'Uma' was direct seeded during the first fortnight of October and harvested in the second fortnight of January in all the years. During summer, vegetables, viz. yardlong bean variety 'Vellayani Jyothika' of 100 days duration, okra variety 'Arka Anamika' of 90 days duration, oriental pickling melon variety 'Saubhagya' of 75 days duration and amaranth variety 'Arun' of 60 days duration, were planted during the first fortnight of February and harvested in the first fortnight of May in all the years.

The recommended quantity of farmyard manure @ 5 t/ha was not applied to rice during *kharif* and *rabi*, as the heavy monsoon rains turn stockpiled manure into watery lumps making handling difficult and spreading manure during rain on saturated soil was found to cause compaction and runoff of manure. Over the time water evaporates, leaving behind the solid materials to be collected and spread on fields during summer. During heavy monsoon rains, farmers are benefitted by organic-rich alluvial soil (*ekkal mannu*) brought in and deposited by annual flood waters, as the experimental sites are located in a flood plain. Farmyard manure having nutrients 0.5% N, 0.2% P₂O₅ and 0.5% K₂O was applied at the recommended rate

of 20 t/ha in yardlong bean, 12 t/ha in okra, 25 t/ha in oriental pickling melon and 50 t/ha in amaranth. Fertilizers were applied @ 90–45–45 kg N-P₂O₅-K₂O/ha in rice, 20–30–10 kg N-P₂O₅-K₂O/ha in yardlong bean, 55–35–70 kg N-P₂O₅-K₂O/ha in okra, 70–25–25 kg N-P₂O₅-K₂O/ha in oriental pickling melon and 50–50–50 kg N-P₂O₅-K₂O/ha in amaranth. Recommended doses of nitrogen (N), phosphorus (P) and potassium (K) were supplied to the different crops through urea, rock phosphate and muriate of potash respectively. Irrigation water was not limiting during any season. The *kharif* rice was grown as fully rainfed, while the *rabi* rice and summer vegetables were grown with supplemental irrigation. Need-based intercultural and plant-protection measures were adopted for the component crops in each system. The soil texture at the test sites was clay loam. The average values as well as ranges of soil properties in experimental fields were: strongly acid pH 4.75 (4.29–5.21), moderately saline electrical conductivity EC 1.15 (0.96–1.34) dS/m, high organic carbon 1.25% (1.02–1.48%), medium available N 386 (341–431) kg/ha, low available P 11.8 (8.7–14.9) kg/ha and medium available K 245 (211–279) kg/ha.

Parameters such as system-equivalent yield, sustainable-yield index, system productivity, relative production efficiency, land-use efficiency and economics (cost of cultivation, gross returns, net returns, sustainable-value index, system profitability, relative economic efficiency and net returns per rupee invested) were used for comparison of cropping systems (Devasenapathy *et al.*, 2008). Soil available N, P, K and nutrient uptake by plants were estimated as per standard procedure. Treatment-wise balance sheets of N, P and K indicating available nutrients in soil at initial stage, nutrients added for raising crop, nutrient uptake by crop, nutrients left in soil after harvesting, actual nutrient gain or loss over initial status and apparent nutrient balance in soil were worked out (Jain and Meena, 2015). Apparent nutrient-use productivity which measures the response in equivalent yield of a cropping system per unit of fertilizer nutrient applied was calculated by the formula as described by Devasenapathy *et al.* (2008) and expressed in kg of equivalent yield/kg of nutrient.

$$\text{Apparent nutrient use productivity} = \frac{\text{System equivalent yield (kg/ha)}}{\text{Quantity of fertilizer nutrient applied (kg/ha)}}$$

RESULTS AND DISCUSSION

System yield and productivity

Maximum rice-grain-equivalent yield was recorded in rice–rice–yardlong bean system which was most productive at 96.9 kg/ha/day and had the highest sustainable yield index (Table 1). This system also revealed the highest relative production efficiency and highest land-use efficiency.

Rice-grain-equivalent yield in rice–rice–amaranth and rice–rice–oriental pickling melon systems were respectively 19% and 34% lower than rice–rice–yardlong bean system. The lowest rice-grain-equivalent yield was recorded in rice–rice–fallow system. Adopting rice–rice–yardlong bean system is thus a productively-efficient alternative to traditional rice–rice–fallow system. Grain and straw yields of rice during *kharif* and *rabi* seasons in traditional rice–rice–fallow system and in other rice-based systems intensified with vegetables in summer fallow were comparable. Summer vegetables including leguminous yardlong bean failed to significantly influence grain and straw yields of succeeding *kharif* rice is attributed to prevailing farmers' practice of removing above ground summer crop residues from field. John *et al.* (1989) reported that yields of rice immediately after cowpea with the above ground residues removed or after a weedy fallow

were similar. However, addition of pre-rice-cowpea residues increased rice yield.

Apparent nutrient-use productivity and soil available nutrient balance

Of the systems evaluated, rice–rice–yard long bean system showed the highest apparent nitrogen-use productivity (Table 2). Expected nitrogen balance was the maximum in rice–rice–fallow system owing to low yield and low N uptake. However, actual N gain of only 13 kg/ha was recorded in rice–rice–fallow system owing to summer weedy fallow between crops. Ventura *et al.* (1986) observed that dry fallow between rice crops decreases the N gain. In rice–rice–yardlong bean system where N loss was expected, maximum actual N gain of 39 kg/ha was recorded which resulted from the fixation of atmospheric N by legume yardlong bean. Rice–rice–amaranth system

Table 1. Yield, rice-grain-equivalent yield (RGEY), sustainable-yield index (SYI), system productivity, relative production efficiency (RPE) and land-use efficiency (LUE) as influenced by introduction of vegetables in rice–rice–fallow system (mean data of 4 years)

Cropping system	Grain/green pod/fruit/leaf yield (t/ha)			Straw yield (t/ha)		System equivalent yield (RGEY) (t/ha)	SYI	System productivity (kg/ha/day)*	RPE (%)	LUE (%)
	<i>Kharif</i>	<i>Rabi</i>	Summer	<i>Kharif</i>	<i>Rabi</i>					
Rice–rice–fallow [#]	4.81	4.60	0.00	5.76	5.42	10.63	0.22	29.13		64.38
Rice–rice–yardlong bean	4.89	4.67	10.70	5.94	5.66	35.39	0.62	96.96	234	91.79
Rice–rice–okra	5.05	4.83	12.50	6.04	5.88	23.29	0.48	63.80	120	89.04
Rice–rice–oriental pickling melon	5.08	4.89	20.19	6.12	5.95	23.50	0.49	64.37	122	84.93
Rice–rice–amaranth	5.18	4.95	16.42	6.29	6.04	28.65	0.60	78.49	170	80.82
SEm±	0.08	0.07		0.06	0.08	1.11		4.79		
CD (P=0.05)	NS	NS		NS	NS	3.09		13.31		

#Farmer practice, *Calculated on rice-grain-equivalent yield basis

Table 2. Apparent nitrogen-use productivity and available nitrogen balance in soil as influenced by introduction of vegetables in rice–rice–fallow system (mean data of 4 years)

Cropping system	Apparent N-use productivity (kg/kg N)*	Initial soil N status (kg/ha)	N added (kg/ha)	N uptake by crops (kg/ha)	Expected balance, gain (+) or loss (–) [(A+B)–C]	Soil-N status after harvesting (kg/ha)	Apparent balance, gain (+) or loss (–) [E–D]	Actual balance, gain (+) or loss (–) [E–A]
Rice–rice–fallow [#]	59	386	180	215	351	399	48	13
Rice–rice–yardlong bean	118	386	300	773	–87	425	512	39
Rice–rice–okra	79	386	295	730	–49	349	398	–37
Rice–rice–oriental pickling melon	63	386	375	938	–177	292	469	–94
Rice–rice–amaranth	60	386	480	579	287	418	131	32
SEm±	1.3			26		14		
CD (P=0.05)	3.6			78		46		

#Farmer practice, *Calculated on rice-grain-equivalent yield basis

showed actual N gain of 32 kg/ha owing to more application of nitrogenous fertilizers in relation to uptake. Apparent N balance was positive in all cropping systems.

Maximum apparent phosphorus use productivity of 221 kg/kg P₂O₅ was observed in rice–rice–yardlong bean system (Table 3). Phosphorus balance was the maximum in rice–rice–fallow system which was owing to low yield and low P uptake. The P balance was negative in all systems intensified with summer vegetables due to high yield and higher P uptake in vegetables. Maximum actual P gain of 1.3 kg/ha was recorded in rice–rice–fallow system due to accumulation of unutilized P in soil. In rice–rice–yardlong bean system, P uptake had caused expected P loss of 34.4 kg/ha to the system. Hence actual P loss of 3.8 kg/ha, which was observed in rice–rice–yardlong bean system can be overcome without necessitating additional fertilizer

application if pre-rice–yardlong bean residues are recycled back into the system. Maintaining a positive actual P balance can increase total N accumulation by leguminous yardlong bean, as P acts as an energy source for symbiotic N-fixing *Rhizobium* bacteria colonizing root nodules.

Apparent potassium-use productivity was the maximum in rice–rice–yardlong bean system (Table 4). Expected K balance was positive in rice–rice–fallow system due to low yield and low K uptake. Maximum expected K balance and actual K gain were recorded in rice–rice–amaranth system due to more addition of potassic fertilizers when compared to uptake. Actual K gain was positive in intensively cropped rice–rice–yardlong bean, rice–rice–okra and rice–rice–oriental pickling melon systems where K loss was expected due to release of exchangeable K into soil solution during flooded *kharif* and *rabi* rice cultivation

Table 3. Apparent phosphorous use productivity and available phosphorous balance in soil influenced by introduction of vegetables in rice–rice–fallow system (mean data of 4 years)

Cropping system	Apparent P-use productivity (kg/kg P ₂ O ₅)*	Initial soil P status (kg/ha)	P added (kg/ha)	P uptake by component crops (kg/ha)	Expected balance, gain (+) or loss (-) (kg/ha) [(A+B)-C]	Soil P status after harvesting (kg/ha)	Apparent balance, gain (+) or loss (-) (kg/ha) [E-D]	Actual balance, gain (+) or loss (-) (kg/ha) [E-A]
		(A)	(B)	(C)	(D)	(E)	(F)	(G)
Rice–rice–fallow [#]	118	11.8	39	40	10.5	13.1	2.6	1.3
Rice–rice–yardlong bean	221	11.8	69	115	-34.4	8.0	42.4	-3.8
Rice–rice–okra	156	11.8	64	103	-27.1	9.5	36.7	-2.3
Rice–rice–oriental pickling melon	142	11.8	71	172	-89.2	5.3	94.5	-6.5
Rice–rice–amaranth	119	11.8	103	129	-14.0	10.3	24.3	-1.5
SEm±	2.1			5.2		0.45		
CD (P=0.05)	5.9			15.3		1.49		

[#]Farmer practice, *Calculated on rice-grain-equivalent yield basis

Table 4. Effect of introduction of vegetables in rice–rice–fallow system on apparent potassium-use productivity and available potassium balance in soil (mean data of 4 years)

Cropping system	Apparent K-use productivity (kg/kg K ₂ O)*	Initial soil K status (kg/ha)	K added (kg/ha)	K uptake by component crops (kg/ha)	Expected balance, gain (+) or loss (-) (kg/ha) [(A+B)-C]	Soil K status after harvesting (kg/ha)	Apparent balance, gain (+) or loss (-) (kg/ha) [E-D]	Actual balance, gain (+) or loss (-) (kg/ha) [E-A]
		(A)	(B)	(C)	(D)	(E)	(F)	(G)
Rice–rice–fallow [#]	118	245	75	223	97	307	210	62
Rice–rice–yardlong bean	177	245	166	493	-82	292	374	47
Rice–rice–okra	106	245	183	449	-21	298	319	53
Rice–rice–oriental pickling melon	98	245	199	536	-92	261	353	16
Rice–rice–amaranth	73	245	324	431	138	346	208	101
SEm±	1.9			18.3		10.3		
CD (P=0.05)	5.3			54.1		35.4		

[#]Farmer practice, *Calculated on rice-grain-equivalent yield basis

Table 5. Cost of cultivation, gross returns, net returns, sustainable-value index, system profitability, relative economic efficiency and net returns per rupee invested as influenced by introduction of vegetables in rice–rice–fallow system (mean data of 4 years)

Cropping system	Cost of cultivation ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Sustainable value index	System profitability (₹/ha/day)*	Relative economic efficiency (%)	Net returns/₹ invested
Rice–rice–fallow [#]	94	145	51	0.17	217		1.54
Rice–rice–yardlong bean	264	516	252	0.40	751	394	1.95
Rice–rice–okra	200	335	135	0.28	415	165	1.68
Rice–rice–oriental pickling melon	195	329	134	0.27	432	163	1.69
Rice–rice–amaranth	225	412	187	0.38	632	267	1.83
SEm \pm		15	6.5				0.04
CD (P=0.05)		41	18.9				0.11

[#]Farmer practice, *Calculated on net returns basis

thus increasing K availability. Patrick and Mikkelsen (1971) suggested that in anaerobic soil, an appreciable amount of NH_4^+ is produced which contribute to the displacement of K from the exchange complex. Patrick *et al.* (1985) indicated that flooding enhances release of exchangeable K into soil solution by stimulating reduction of Fe^{3+} to Fe^{2+} and Mn^{4+} to Mn^{2+} , which displaces K^+ from cation-exchange sites. In rice–rice–yardlong bean system, K uptake had caused expected K loss of 82 kg/ha to the system. Hence actual K gain of 47 kg/ha observed in rice–rice–yardlong bean system could be enhanced if yardlong bean residues are recycled back into the system.

Economics

Cost of cultivation for rice–rice–yardlong bean system was the maximum, which was due to high cost incurred for erection of support (*panthal*) for trailing yardlong bean. (Table 5). However, this high cost of cultivation was more than compensated by highest rice grain equivalent yield (35.39 t/ha) and maximum gross returns obtained in the system (Table 5). Net returns per rupee invested was 1.95, with a net return of ₹2,52,000/ha and sustainable value index 0.40 were also maximum in this system, resulting in higher system profitability of ₹751/ha/day and relative economic efficiency of 394%. The lowest cost of cultivation of ₹94,000/ha was recorded in traditional rice–rice–fallow system as summer fallow saved on agricultural input and labour costs. Consequently, gross returns of ₹1,45,000/ha, net returns of only ₹51,000/ha and net returns per rupee invested was 1.54 for this traditional system were minimum. Farmers participating in on-farm research, after having evaluated introduction of vegetables in traditional rice–rice–fallow system had found improved rice–rice–yardlong bean system to be economically beneficial which in turn raised their social status.

On the basis of 4 years of farmer's participatory experimentation, it can be concluded that intensification of tra-

ditional rice–rice–fallow system in irrigated lowland fields through introduction of legume vegetable yardlong bean in summer fallow along with recycling of pre-rice-yardlong bean residues back into the system could be recommended for realizing higher productivity, profitability and soil health.

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